In measuring visibility during the 24-hour day the following factors should be applied, owing to the variations in seeing mentioned in the preceding paragraph:

First. Angle of light rays illuminating the object or target.

Second. Condition of sky as to cloudiness, twilight starlight, and moonlight.

At nighttime visibility may be measured by observing several lights in a row, the lights to be screened by glasses having varying degrees of transparency; or a single light could be used, the observer peering through smoked glasses at the point of observation. Experiments are now being made to develop a standard visibility measurer in which a screened light is viewed through glasses of differing opaqueness.

THE AURORA OF MARCH 7-8, 1918.

By HERBERT LYMAN and CHARLES F. BROOKS.

[Dated: Weather Bureau, Washington, July 3, 1919.]

SYNOPSIS.—After discussing auroral phenomena in general, including types, latitude variation, periodicity, height, and cause, this article describes the principal features of the remarkably brilliant aurora of March 7–8, 1918, and presents a large number of detailed accounts by observers in the United States.

A chart of the United States shows places from which reports of the aurora were received. To facilitate intercomparison the descriptions have been grouped and discussed by latitude belts of 2½° each, for as would be expected, the display was pretty much the same at the same latitudes.

The aurora became visible at dusk, March 7 and attained its greatest brilliance, generally, at 9:30 p. m. (90th Meridian Time). Since no display is homogeneous, however, there are variations in the times of greatest brilliance and in the appearance of details of the display, although there is general unanimity concerning the times, colors, brilliance, and aspect, among widely scattered observers. The descriptions of the positions of arches, particularly of a prominent red one, make it obvious that the actual location of the aurora is the factor which determines its aspect, and the distance to which it can be seen, while the lack of streamers in the display at most southern points show that the clearness of the air limits its visibility.

It seems that the magnetic disturbance accompanying this aurora was a repetition, after three 27-day intervals, of the large magnetic storm of December 16–17, 1917. There was a considerable disturbance on January 12, and a minor one at the end of the next 27-day interval in February. Auroras on April 4, 5, and 6, marked the end of this strong series, which was probably caused by 5 successive presentations of an active area on the sun.

INTRODUCTION.

Auroras have always excited widespread interest not alone because of their wonderful formation and beautiful coloring but also because of their very mysteriousness. A superb example of the aurora was that which occurred on the night of March 7–8, 1918. This aurora was witnessed simultaneously over practically the entire North American continent and in Europe. In the United States auroras are not often seen south of latitude 40°, yet in this instance the phenomenon was observed as far south as Miami, Fla., where the observer described it as "a brilliant illumination of the northern sky." Aside from the unusual geographical extent of this auroral display, the most noteworthy features were its brilliance, coloring, and extent over the sky. Several observers said the light from the aurora equalled the light from the full moon. The coloring was magnificient. Various shades of red were generally observed as well as greens and the usual yellows and white.

Reports and notes on the aurora of March 7–8, 1918, received from a large number of regular and a few cooperative Weather Bureau stations, where the sky was not obscured (see fig. 1), also a few reports from observers in other parts of the world, have been assembled and tabulated in groups by latitudes.

It is hoped that these descriptions may be usable for any studies of the geographic synchronism of the times of great brilliance, and for comparisons of the times of occurrence and appearance of particular features as seen at different places. There is such a mass of detail, however, that it may be best to precede the local descriptive matter with (1) a general discussion of the aurora polaris as to its essential features and probable cause, (2) the inferred make-up of great auroral displays, and (3) a summary of the principal features of the aurora of March 7–8, 1918.

AURORA POLARIS.[1]

By W. J. HUMPHREYS.

The aurora polaris is a well-known but imperfectly understood luminous phenomenon of the upper atmosphere. * * *

Types.—While no two auroras are exactly alike, several types have been recognized, such as arcs, bands, rays, curtains or draperies, coronas, luminous patches, and diffuse glows. The arcs normal to the magnetic meridian, often, but not always, reach the horizon. Their under edge is rather sharply defined, so that by contrast the adjacent portion of the sky appears exceptionally dark. The rays, sometimes extending upward from an arch, at other times isolated, are parallel to the lines of magnetic force. Many auroras are quiescent, others exceedingly changeable, flitting from side to side like wandering searchlights, and in some cases even waving like giant tongues of flame.

Latitude variation.—The aurora of the Northern Hemisphere occurs most frequently, about 100 per year, at the latitudes 60° (over the North Atlantic and North America) to 70° (off the coast of Siberia). Its frequency appears to be less within this boundary, while with decrease of latitude it falls off so rapidly that even in southern Europe it is a rare phenomenon. At the same latitude it is distinctly more frequent in North America than in either Europe or Asia.

The distribution of auroras in the Southern Hemisphere is not so well known, but it appears to be similar, in general, to that of the northern.

Periodicity.—It is well established that on the average auroras are more numerous during years of sunspot maxima than during years of spot minima. They also appear to be more numerous before midnight than after. Relations of frequency to phase of the moon, season, etc., have also been discussed, but with no conclusive results.

Color.—Many auroras are practically white. Red, yellow, and green are also common auroral colors. Some streaks and bands are reddish through their lower (northern) portion, then yellowish, and finally greenish through the higher portions. Much of the light is due to nitrogen bands, but the source of the most prominent line of the auroral spectrum, λ .557μ (green), is not known. It has often been attributed to krypton, but other conspicuous krypton lines are absent; besides krypton is too heavy to exist at auroral heights in sufficient abundance to produce a spectrum of such brilliance.

There is good evidence that this green light, the light that produces the "auroral line," is always present in the sky, though whether wholly of auroral origin, or due in part to bombardment by meteoric dust, or to some other cause, is not known.

Height.—The problem of the height of auroras has often been investigated, but only recently solved. By simultaneously photographing the same aurora from two stations against a common background of stars, and measuring the parallax obtained, Störmer[2] and Vegard and Krogness[3] have secured many excellent height measurements. The upper limits of the auroral light vary from about 100 kilometers to over 300 kilometers; and the lower limits from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, one at 100 kilometers, the other at 106 kilometers.

[1] Quoted from "Physics of the Air," Journ. Franklin Inst., Oct., 1918, pp. 481-484.
[2] Terr. Magnet. and Atmos. Elec., 1916, 21: p. 157.
[3] Terr. Magnet. and Atmos. Elec., 1916, 21: p. 169.

Cause.—The fact that brilliant shifting auroras are accompanied by magnetic storms renders it practically certain that they, and presumably therefore all auroras, are due to electric discharges; and the further fact that they vary in frequency with the sunspot period indicates that this current either comes from or is induced by the sun. For some time it was thought probable that auroras are caused by negative particles shot off from the sun and entrapped by the magnetic field of the earth. On the other hand, Vegard [4] has given strong arguments in favor of the α particle which is positively charged, and Störmer [5] has found at least one case that required the positive charge to account for the observed magnetic disturbance.

The evidence, then, while not conclusive, indicates that auroras are due to streams of α particles in the upper atmosphere shot off by radioactive substances in the sun.*

the sun. We may assume that at such times great jets or streams of electrified matter (electrons perhaps), akin to cathode rays in a vacuum, are projected with high velocities outward, and that occasionolly some of these jets cross the earth's orbit or pass near to it, being when leaving the sun in a general radial direction, bent backward, for obvious reasons.

That electrified matter in a vacuum does move in jets or streams for indefinite distances is a fundamental fact. Moving charges of the same name in paths, straight or curved, act like parallel currents and attract one another, the more as their velocity is greater, until the static repulsion of such like charges sets a limit to further approach. It is possible that the space around the sun may be crossed by many such jets or streams of electrified matter moving at very high velocities into the vacuous space. The coronal streamers may be the visible composite effects of the projected jets. Such electrified jets may act

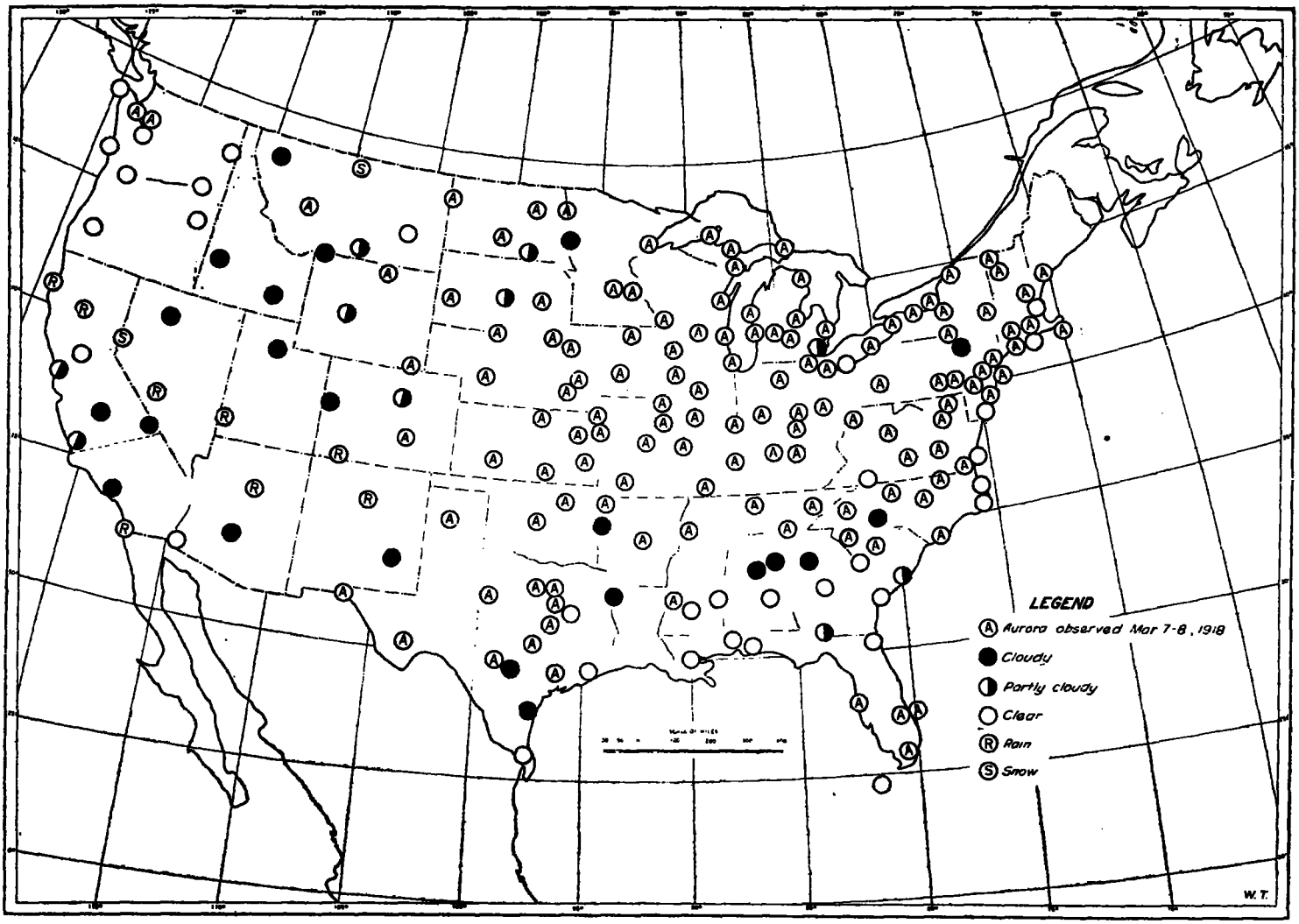

FIG. 1.—Where the aurora of Mar. 7-8, 1918, was observed.

INFERENCES CONCERNING AURORAS.

CERTAIN PHYSICAL FACTS REGARDING THEM.[6]

By ELIHU THOMSON.

It seems doubtful if any extensive auroral display has occurred without coincident existence of exceptional areas of disturbance on

inductively by proximity to the earth or directly by conduction of electricity to the earth's outer atmosphere.

In the present paper, however, it is hoped to prepare the way for further study by pointing out certain physical facts regarding the relations of auroral phenomena to the earth and its atmosphere; to locate and give direction to the streamers seen in auroras; and to explain the nature of the so-called auroral arch, the zenith crown, and other characteristics. It is believed that the following propositions may be shown to be true:

1. Streamers seen in auroras, singly or in composite masses, are in reality vertical, or approximately so, to the earth's surface, nearly parallel when adjacent, and only slightly divergent even when miles apart; the divergence being due to curvature of the earth's suriace.

2. In many auroras, the streamers appear to be located in bands or zones more or less wide in latitude, extending generally in east-and-west direction, or forming belts or zones between parallels of latitude in which the streamers extend vertically upward like trees in a forest. * * * The same auroral appearances are possible to be seen alike at different places simultaneously only when a system of vertical streamers exists. * * *

[4] Phil. Mag., 1912, 23:211.

[5] Terr. Magnet. and Atmos. Elec., 1915, 20:1. See also, 1917, 22:23 and 97 (abstr. Sci. Am. Supp., Mar. 30, 1918, p. 197).

* For a good, well-illustrated, popular account of the theory of the aurora, see Sci. Am. Supp., Aug. 31, 1918, pp. 132-134.

A very complete bibliographical, mathematical discussion: "Bericht uber die neueren Untersuchungen am Nordlicht," by L. Vegard seems to be the best aurora paper now in print: Jahrbuch der Radioaktivität und Elektronik, 1917, 14:383-465, 7 figs., 5 tables. The bibliography, pp. 385-387, contains 86 titles. The titles of the five chapters are: I, "The most important characteristics of the aurora"; II, "Historical summary of the theory of the aurora"; III, "Establishment and foundation of the cosmical ray hypothesis and theory of the aurora"; IV, "The characteristics of the aurora in the light of the cosmical ray theory"; and V, "The physical nature of the cosmical rays."

[6] Quoted from Proc. Nat. Acad. Sci., Washington. (Reprinted in Sci. Am. Supp. 2151, Mar. 24, 1917, pp. 182-183.)